



Aircraft Engineering and Aerospace Technology

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Article information:

To cite this document:

A.M. PATRICK, CEng, MIERE, (1972),"Automatic landing and microwave guidance system potential", Aircraft Engineering and Aerospace Technology, Vol. 44 Iss 8 pp. 19 - 22

Permanent link to this document:

<http://dx.doi.org/10.1108/eb034932>

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Automatic landing and microwave guidance system potential

By A. M. PATRICK,* CEng, MIERE

The striking advances in ILS performance in the last decade are related to the impetus given by specific changes in operational requirements, particularly as regards automatic landing systems. The article goes on to review the long term project for microwave landing guidance systems, planned to see service in the 80's, with which ILS will co-exist to an extent, and for a period, impossible as yet to foretell.

B. E.A. IS AWAITING final certification from the Civil Aviation Authority to operate its Trident IIIB's with a 12ft decision height with an associated runway visual range of 300m. The operation will require the pilot to confirm, at decision height, that the aircraft's attitude, position and trajectory is satisfactory in azimuth, and that there is adequate visibility for roll out, with the proviso that the aircraft will be equipped with pilot's visual displays for directed roll out. The pilot will still have the option, down to decision height, to pull out and go round again.

At their last technical conference, a number of IATA member airlines reported progress from the implementation of airborne fits for Autoland and Auto Approach, together with a statement of the success rate being achieved at many of the better equipped airports in the world. The great majority of this information was extremely encouraging and it is to be hoped that IATA and the governments concerned will join together in a programme of implementation of modern ILS which will enable the travelling public, the airlines and airport operators, to gain maximum benefit from the very significant investments already made in airborne equipments.

The Trident was the first aircraft in regular service which was designed with Autoland in mind, but the Lockheed TriStar and the DC10 are entering service with a similar capability. Retro-fitting is of course an expensive investment and one would not expect many aircraft so to be treated. There is, however, a clearly recognised pattern of requirements of category II ILS at any runway in any weather condition where a modern high performance jet aircraft is operating, and more recognition of this has still to be attained. Some authorities have been historically educated

to understand that landing in clear weather was no problem, and it is up to IATA member airlines and industry to join together in achieving more widespread implementation of category II facilities in all weathers, particularly where marginal runway length is involved, including, of course, appropriate ILS facilities.

It will be appreciated that in a broad sense, ILS is used operationally in two ways, either as part of Autoland, or by pilots in aircraft not fitted

* Plessey Radar.

CATEGORY I	Operation down to a minima of 200ft decision height and runway visual range of 800m with a high probability of approach success
CATEGORY II	Operation down to a minima below 200ft decision height and runway visual range of 800m and to as low as 100ft decision height and runway visual range of 400m with a high probability of approach success.
CATEGORY IIIA	Operation down to and along the surface of the runway, with external visual reference during the final phase of the landing down to runway visual range minima of 200m.

Fig. 1.—Generalised definitions of ICAO categories of operation.

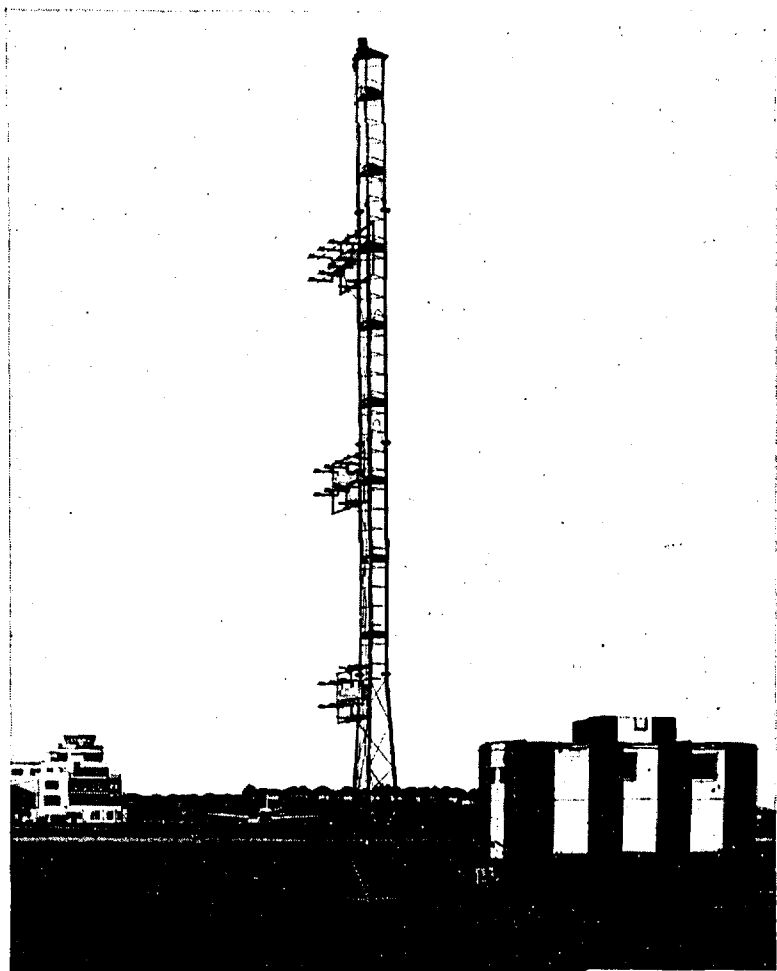


Fig. 2.—Typical installation of STAN 38 ILS glidepath.

for Autoland, in its role as an approach to landing aid. However, the great improvements made in ILS to gear it to Autoland are available and beneficial to users of ILS in the manual application.

Several objectives had to be tackled in developing the Plessey STAN 37/38 ILS system to meet the specifications which had been drawn up for category III performance. But the design team had already produced the

STAN 7/8 which had gone a long way towards satisfying the goal and consequently it had a wealth of operational and technical experience.

Improving reliability and integrity

One of these objectives was extremely high reliability and remembering that the accepted failure of an automatic landing shall have a probability of less than one in ten million, achieving this was no mean task. Fortunately, technical advance in electronics had been proceeding apace and the availability of solid-state and other techniques was at hand to provide new orders of stability and dependability.

But improving signal quality too was vital to give greater protection against course bends caused by reflections from buildings, high ground, taxiing and overflying aircraft in the vicinity of the airport. In the Plessey STAN 37 ILS Localiser this is obtained by a unique technique called 'Quadrature Clearance' which has been patented, and not only gives a greater rejection of unwanted reflections but does so in a way that requires less equipment than other current systems, and at one stroke reduces the amount of equipment required, consequently increasing system reliability.

The basic requirement for an ILS localiser is that it shall provide signals sufficient to allow satisfactory operation of a typical aircraft installation out to 25 miles on a sector of $\pm 10^\circ$ extending from the centre of the localiser aerial, and out to 17 miles between 10° and 35° from the front course line. In special cases a reduced coverage may be permitted.

To avoid floodlighting a sector of $\pm 35^\circ$, which would result in a very large number of reflections from buildings, uneven ground and aircraft flying in the region, modern ILS equipment provides the mandatory cover by using two beams. One is a strong beam using the full aerial aperture to give cover over $\pm 10^\circ$ and known as the 'course' beam. The other

the fact that the 90Hz and 150Hz tones, which give the 'fly left', 'fly right' indications to the pilot, of the course beam are in phase quadrature with the 90Hz and 150Hz tones of the clearance beam. Because as at most points on the approach path either the course or the clearance signal predominates, it follows that the vectorial addition of these two signals will produce a resultant which is almost equal to the predominating signal. As the course signal is always strong within a few degrees of the runway centreline, any reflected clearance signals present will have very little effect at the aircraft receiver when vectorially added to the large course signals. Course bends are thus minimised and obstacles and uneven terrain in the clearance region have significantly less effect in the phase quadrature system than they would in the two-carrier system referred to above.

The order of improvement in rejection of unwanted reflections by the phase quadrature system speaks for itself. If on a given site a beam bend of 0.4 per cent difference in depth of modulation occurs with the two-frequency method, quadrature clearance would reduce it to 0.14 per cent DDM. This difference in depth of modulation is the percentage modulation depth of the larger signal less the percentage modulation depth of the smaller signal.

Many installations have a standby transmitter channel. This means that with a two-frequency system one would need four transmitters, two for main, two for standby, giving the STAN 37/38 an advantage of 1 : 2 in equipment simplicity and as a result, increased system reliability.

Flexibility in siting and equipment configuration

Siting has always been crucial in securing optimum ILS performance. The characteristics which predominate at airport sites can be classified

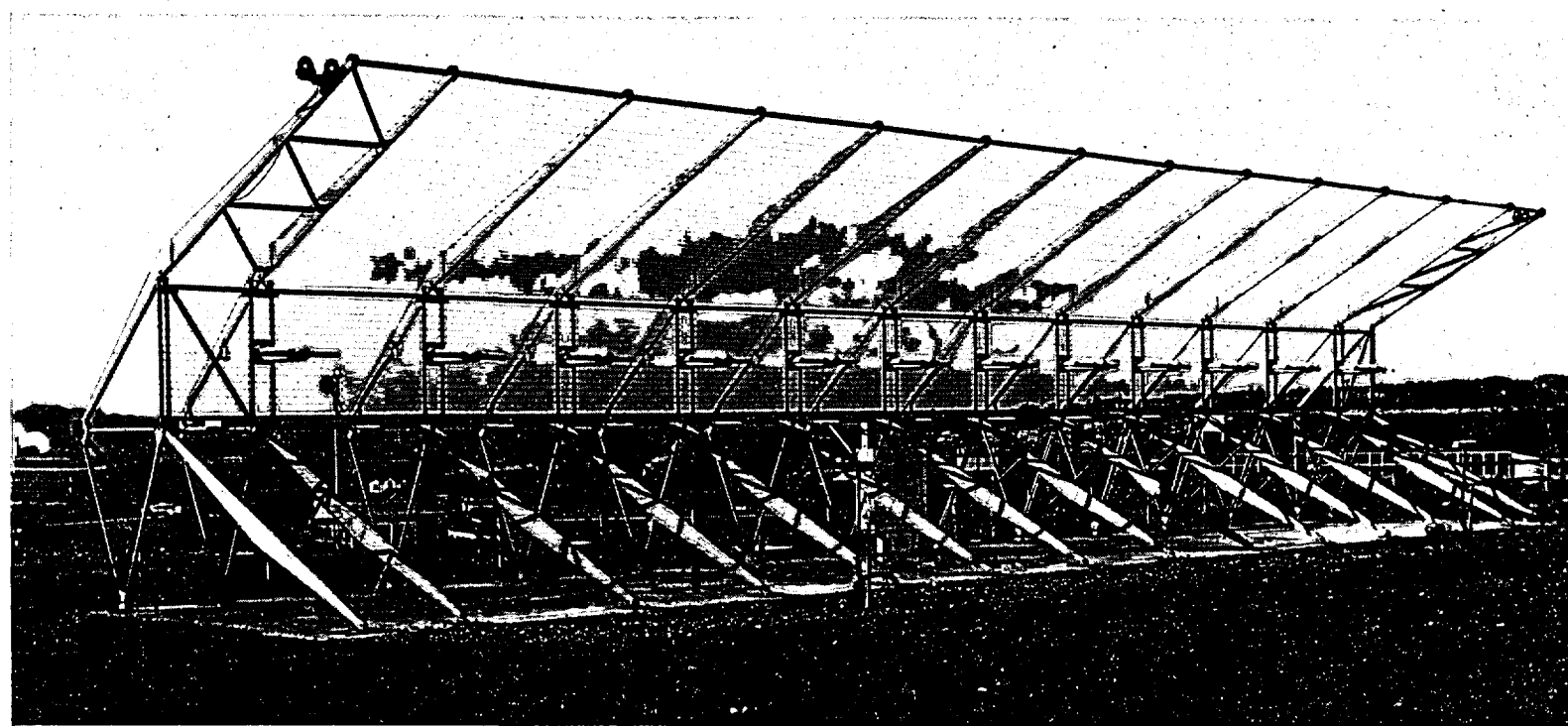


Fig. 3.—Single aperture 12-dipole aerial of the STAN 37 ILS localiser.

beam is known as the 'clearance' beam and gives the cover beyond 10° out to 35° on either side of the course beam using only part of the aperture. Equipments other than the STAN 37 Localiser use two transmitters for this purpose at frequencies f_1 and f_2 , which are close enough to be within the bandwidth of the aircraft ILS receiver.

The STAN 37 Localiser, however, uses a method whereby only one transmitter radiates a course beam and a clearance beam generated from a common carrier but bearing a phase quadrature relationship to each other.

In this system, capture effect at the aircraft receiver is obtained due to

into quite a small number and Plessey has a range of different aerials which is normally adequate to ensure a satisfactory ILS performance. The STAN 37 Localiser, for example, can be supplied with a single or double aperture aerial with a corner reflector or with various heights of fence type reflectors to suit conditions.

The double aperture aerial narrows the course beam to $\pm 5^\circ$ which can be advantageous at airfields with large buildings near the course line. Corner reflectors, which restrict the vertical radiation, will reduce unwanted reflections from overflying aircraft. Where runway length raises obstacle clearance considerations, the fence type reflector, which is lower than the corner reflector, is often selected.

Again, three types of STAN 38 Glidepath aerials are available:

- (a) For sites with relative freedom from obstructions or changes in terrain
- (b) For those with a restricted beam forming area in front of the aerial mast, and
- (c) For those where obstacles such as hills, large buildings or fuel tanks subtend significant horizontal and vertical angles.

As well as flexibility in choice of aerial, there is another aspect of ILS design where flexibility is important. This is the possibility that in the lifetime of an ILS installation the runway it serves may be upgraded to a higher ICAO category, and hence require a higher category of ILS service. It is important to remember that although frequent reference has been made to ICAO categories I, II and III in respect of ILS, that

aerials available and by use of dualisation and monitoring to the extent necessary, to give the category performance required. It is a very flexible system and dualisation can be carried out without equipment redundancy to provide custom-built installations.

Long term landing system development

So far it has been shown that ILS has been developed to a high pitch and it has a continuing part to play in the planned expansion of aviation. However, in considering the likely changes in operational requirements between now and the end of the century, a good deal of thought has been given to the ultimate in landing systems. This has reached a firm concept stage but the planned timescale is a very tight one for hardware to reach operational status, and spans the best part of a decade.

Even then, it will take some time for the new system to be fitted world-

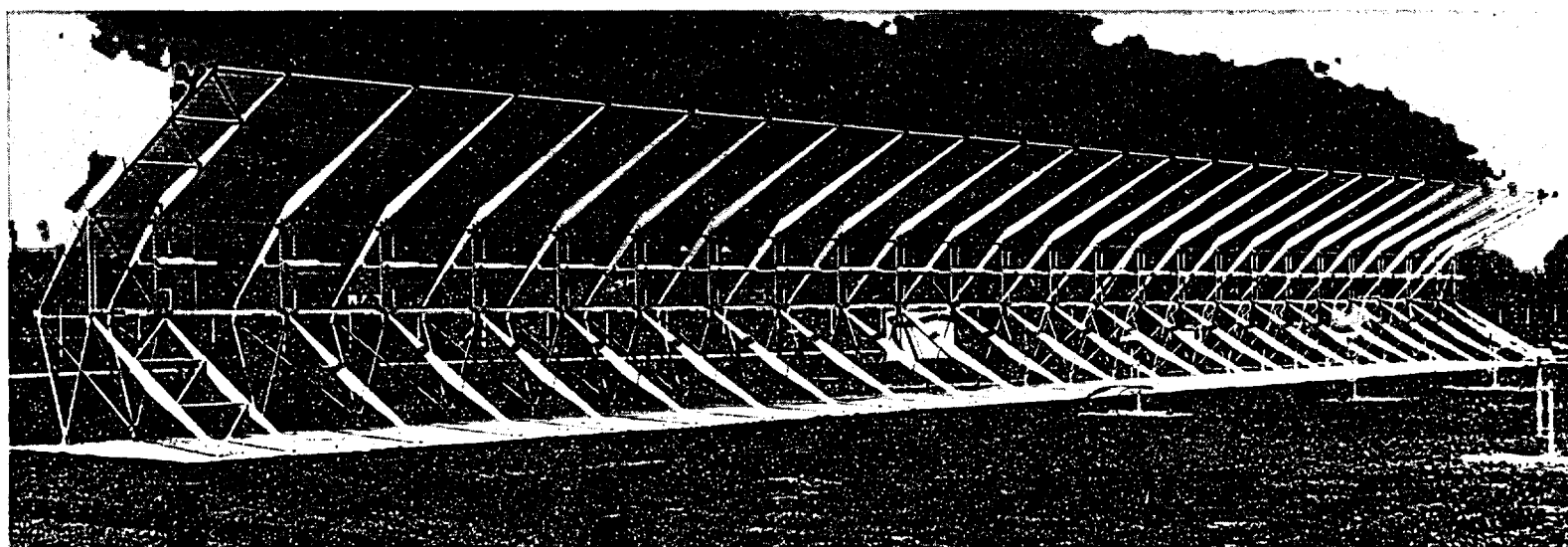


Fig. 4.—Double aperture 24 dipole aerial of the STAN ILS localiser.

other aspects 'in the loop' such as runway length and lighting, and the aircraft ILS installation itself, are also categorised by ICAO. The pilot, too, must be qualified in respect of the aircraft he flies, to carry out categorised landings. Upgrading of ILS therefore is seldom carried out in isolation and is almost always allied to considerations of the runway itself in relation to length, lighting, obstacle clearance etc. for the category concerned. It will also, for category III involve provision of accurate measurement of runway visual range.

For ILS the difference between categories is largely a matter of degree in terms of signal pattern quality and reliability of service. For both these factors, good equipment engineering, of course, contributes but the quality of signal pattern is also very much a function of site characteristics and these are generally unalterable. Quadrature clearance, already described, helps and so does correct choice of aerial. A double aperture STAN 37 localiser aerial instead of a single aperture one, for example, may solve a problem on a given site. Sites are, of course, always surveyed initially as regards ILS and the other characteristics relevant to runway categorisation.

On the question of reliability of service, the inherent high equipment reliability of the STAN 37/38 can be enhanced by provision of dual channel systems either with the standby transmitter running cold, 20sec changeover, or running hot, instantaneous changeover. Additional monitoring can also add its contribution by giving status indication of both channels to confirm that the ILS is operating in its optimum condition.

Equipment configurations are not uniquely specified in ICAO Annex 10 for the various categories. A straightforward, single channel, STAN 37/38 has, in fact, by virtue of its design, the parameters necessary to provide a radiation pattern for categories I, II or III on a good site. STAN 37/38 configurations for particular sites are therefore selected from the range of

wide in place of ILS on the ground and in aircraft, and it is by no means clear that it will be an economic or necessary replacement for ILS at many of the smaller airports. ILS will, therefore, co-exist for a long time, in some cases perhaps indefinitely, with the new system known as the landing guidance system (LGS). Because all the indications are that it will operate on microwave frequencies, the system is sometimes referred to in industry as the microwave landing system but we will use the term LGS by which it is referred to by the authorities. Some aspects are worth mentioning in more detail because the project, being underway, is topical and its implications, politically and commercially, are far reaching.

LGS operational requirement

The decision to seek an ultimate replacement for ILS was based on examination of the likely air traffic situation of the 80's including SST's at airports imposing demands beyond the capabilities of conventional ILS because of certain of its inherent limitations.

The requirements that ILS fails to meet are:

- (a) Sufficient flexibility in that the angles of approach coverage are fixed and too narrow to cater for aircraft capable of making curved approaches. To make maximum use of existing airports in future, flexible precision approach paths, both vertical and lateral may have to be used, and this is beyond the scope of ILS.
- (b) A landing rate consistent with the normal visual flight rules rate.
- (c) High precision guidance for roll out, missed approach and overshoot guidance.
- (d) Coverage for vertical take-off and helicopter aircraft.

These are seen as some of the essential criteria for LGS, which is envisaged as providing departure guidance as well as highly flexible approach

landing guidance. In addition LGS must have freedom from siting restrictions.

An operational requirement (OR) for LGS has been drafted and clearly it can only be met by a completely new system. The OR is as specific as it can be, but remembering that it will about 10 years before the system enters service and for economic reasons alone it must have a life of at least 20 years, the assessment of some aspects of the air traffic situation has meant using a crystal ball with, as it were, an extremely long focal length. The draft OR therefore understandably contains several reservations.

An interim solution deferred

The question of a replacement for ILS had been active for some time and Britain, which has always taken a lead in navaid development, devised a system known as correlation protected ILS (CPILS) using hyperbolic principles, before the LGS concept was formulated as such.

CPILS was conceived at RAE Farnborough in the early 60's as a new

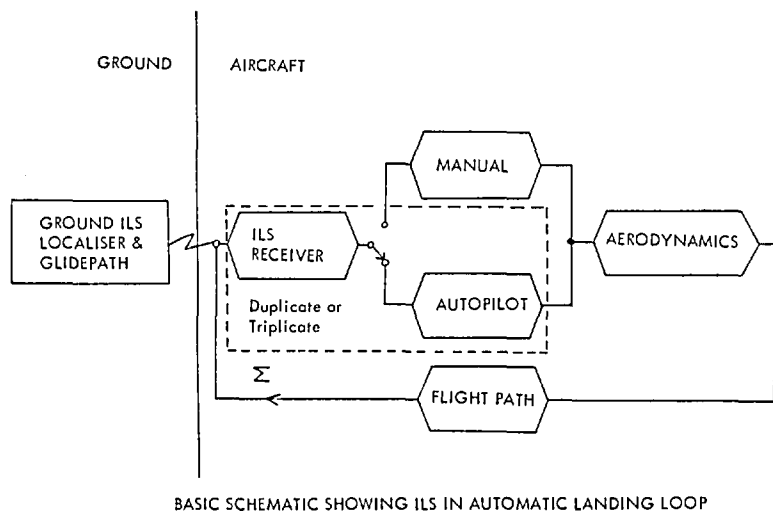


Fig. 5.—Basic schematic showing ILS in automatic landing loop.

generation ILS which would be compatible with the traditional ILS during changeover phase and yet be a superior system in its own right. Plessey Radar worked together with RAE to provide a fully engineered system which was and still is installed at Farnborough.

Despite its many attractions, the higher councils concerned ordained that CPILS was an interim solution rather than a final one, and should not be implemented as an ICAO approved system. Nevertheless, CPILS has fulfilled its promise and meets category III performance standards, even when flying a 2½deg glidepath over the famous 'black sheds' on the approach at Farnborough. The equipment remains operational and has provided a vast amount of research results in the application of C-band to landing guidance systems. This information will be immensely useful for either scanning beam or doppler ILS studies and developments in relation to LGS, and certainly the existing CPILS will make an excellent test tool against which any other newly developed landing system can be measured.

In addition to the many enquiries made from abroad as to its availability, Plessey Radar has recently received one, prompted by the US, in which recognition was given to the fact that it was the only system in existence on which the proposed space tug could be landed if the space shuttle programme is implemented.

LGS programme

The improvements to conventional ILS already described are such that the All-Weather Operations Panel (AWOP) of ICAO recommended that its term as an ICAO protected aid due to expire in 1975 be extended by 10 years and this received formal ICAO approval early this year.

This extension of the service life of ILS gives limited breathing space to

allow LGS to be tackled in a considered fashion and is one reason why interim solutions such as CPILS have not been favoured. Starting off with establishing the best possible OR initial appraisal will be made of the system concepts proffered at the end of this year and a selection made of the most promising by about the middle of next year. Prototypes would then be built and trials carried out, leading to adoption of the chosen system by mid-1976. This will be followed by the preparation of all ICAO Annex 10 material and final engineering, setting-up of production lines, installation and the many other activities associated with introducing into service the ground and airborne elements of a major and completely new navigational aid.

These phases not only involve time but will also cost a great deal of money. The costs are not known but they will certainly be in the multi-million pound bracket, and inevitably, on a winner-take-all basis, a great deal of capital is likely to be spent without any return.

LGS adjudication and administration

A project of the nature and magnitude of LGS, with its opportunities for national prestige and financial gain, is always open to extreme political and commercial pressures unless it is conducted against an internationally agreed procedure imposing safeguards. In the case of LGS, ICAO will act in effect as the referee, and the decision-making machinery has been set-up to suit this timescale.

ICAO approval of the OR will be based on draft ORs already produced by the all-weather operations panel of ICAO itself, special committee 117 or the radio technical commission in America and the NATO industrial advisory group, which show a large measure of agreement. ICAO will then issue this and seek proposals from member states of systems which they would be prepared to sponsor. Industry will, therefore, not deal directly with ICAO but only through their own government, which will decide what indigenous proposal they will sponsor. The response from member states is due at the end of 1972. ICAO will be responsible for instituting and monitoring the subsequent phases and will provide the forum for final agreement on adoption. The first LGS system, assuming time scales are met, would enter service in about 1979/80.

Notwithstanding the importance and urgency of LGS, ICAO and other bodies have stressed that its furtherance is not incompatible either with continued use of ILS and, or, its improvement.

Contending techniques

With LGS still at the OR stage there is little to be said about the system, but it is well established that either conventional scanning beams or doppler scanning are most likely to provide the radiated pattern. Both have their merits and the issue is wide open. Already a great deal of study on both has been done and limited experience on these techniques has been gained in several countries.

Conclusion

To summarise, landing guidance will be provided over at least the next 30 years by ILS and LGS. ILS will continue in use as the approved landing aid until at least the mid 80's by which time LGS, according to present plans, should have come into service at some of the world's major airports. This will be followed by the use of LGS on a wider scale, at a rate which will depend on the operational necessities of the time and also its economics.

The LGS project is seen as offering a unique opportunity to show preparedness for the air traffic requirements of the 80's and beyond by co-ordinated international action, already in train, bringing the world's best operational and technical resources to bear now on this complex problem.

Britain, so long a pioneer in navigational aids, can be counted on to make a notable contribution and already much ground work has been done to this end.